Analysis of Three-Dimensional Roller Performance in a Micro-g Environment

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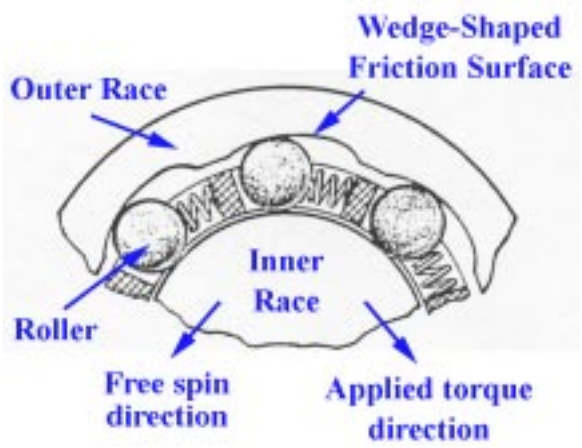
Evolution of One-Way Clutches

- Allow torque to be transmitted in only one direction

Ratchet

- Stops at limited number of positions
- Limits torque that can be applied

Rollers



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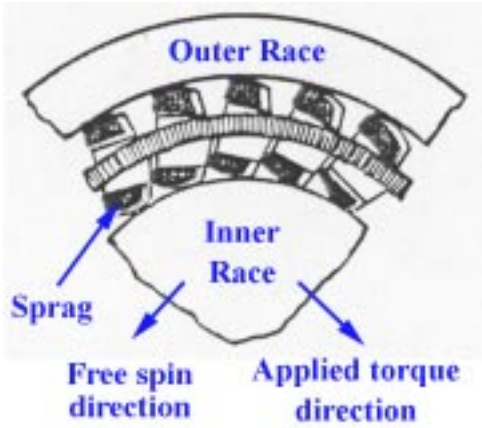
- Rollers wedge in one direction and roll in the other
- Nearly infinite number of stop positions

Sprags



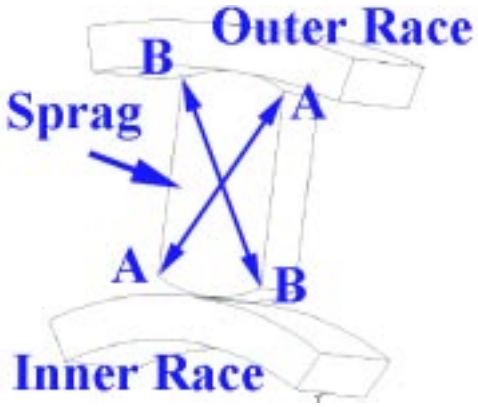
‡

- Two diagonals of sprag are different lengths, with one greater than the distance between the races
- Nearly infinite number of stop positions

† Lowell Corporation *Ratchet Technology* catalog
‡ *Mechanisms and Mechanical Devices Sourcebook*

Advantage of 3-D Sprags over 2-D Sprags

2-D Sprags



- Require lubricants
  - ⇒ Slip in thermal vacuum
- Two “line” contacts
  - ⇒ Require tight tolerances
- Small contact angle
  - ⇒ Results in high stress

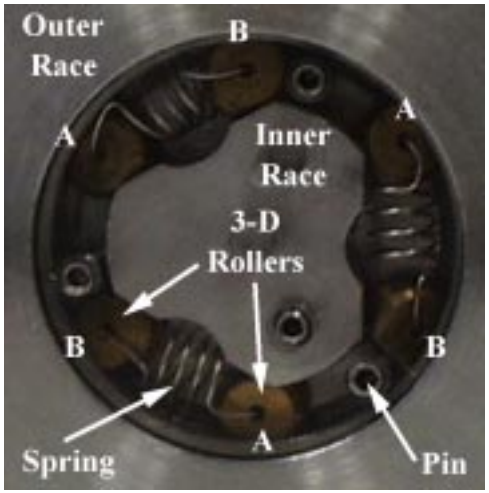
NASA 3-D Sprags

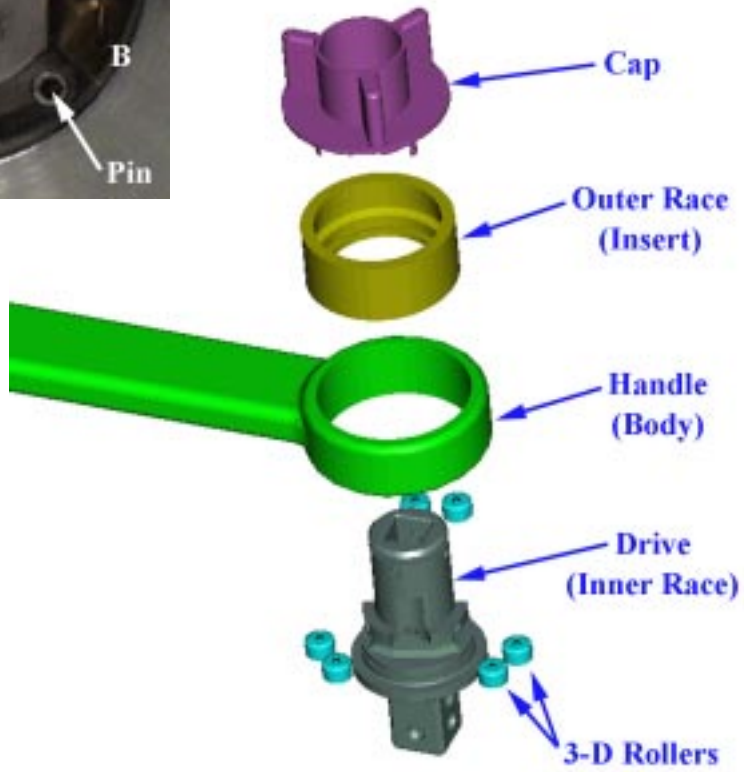
- Require no lubricants
  - ⇒ No slipping in thermal vacuum
- Four “point” contacts
  - ⇒ Allow loose tolerances
- Large contact angle
  - ⇒ Results in low stress

What We're Doing

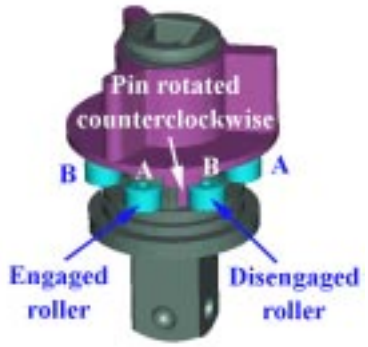
- Replacing the traditional ratchet mechanism in a hand wrench with three-dimensional (3-D) sprags and rollers
- Why?
  - Ratcheting wrench tools work inefficiently in confined spaces
  - Use of ratcheting tools during extravehicular activity (EVA) creates other problems
    - High back drive torque
    - Inability to lock in both directions
    - Lubrication
    - Ratcheting motion is fatiguing
- What advantage is there?
  - Short back throw
  - Lower back drive torque
  - No lubricants
  - Ability to lock in both directions
  - High maximum torque
  - Lower perceived mental workload

EVA 3-D Roller Wrench Operation

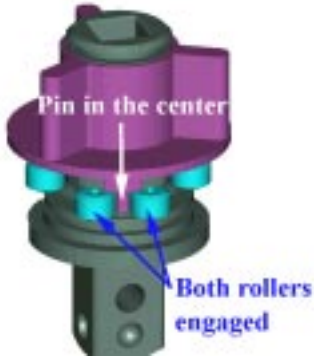




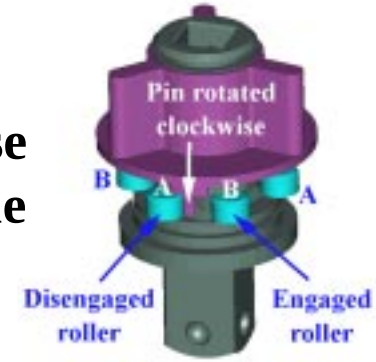
Counterclockwise torque



Torque in both directions



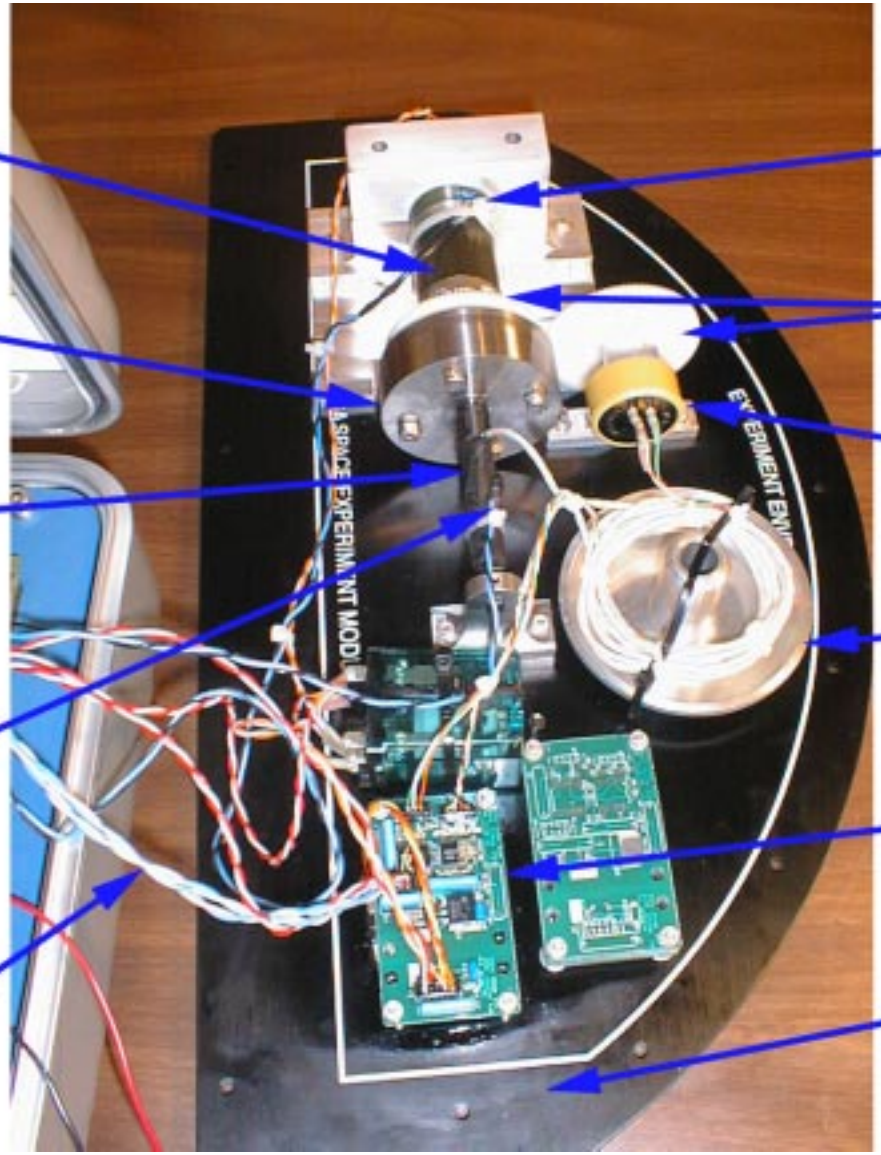
Clockwise torque



Space Experiment Module Experiment

- Flew 3-D roller mechanism in space experiment module (SEM) inside get away special (GAS) canister on STS-95 [October 1998]
- Measured torque when 3-D rollers were used repeatedly in period of extended weightlessness
  - Applied torque of 30 in-lbf
  - Back drive torque less than 7 in-oz

SEM Experiment Test Setup

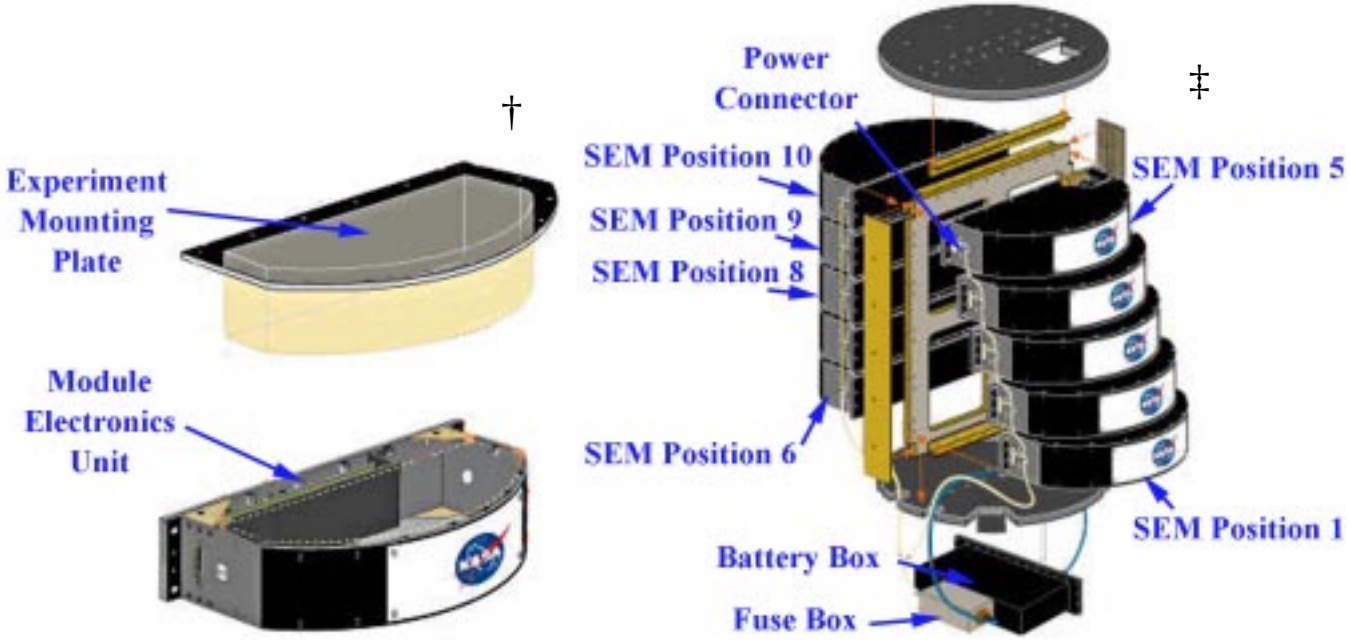


SEM Experiment Sample Data Run

Time	Event
T = 0m : 0s	Turn on the electronics
T = + 0m : 1s	Turn on the motor
T = + 2m : 40s	Collect torque data
T = + 2m : 50s	Reverse motor
T = + 2m : 51s	Reverse motor again (toward the original direction)
T = + 3m : 1s	Stop collecting data
T = + 3m : 2s	Turn off motor and electronics

SEM Experiment Integration

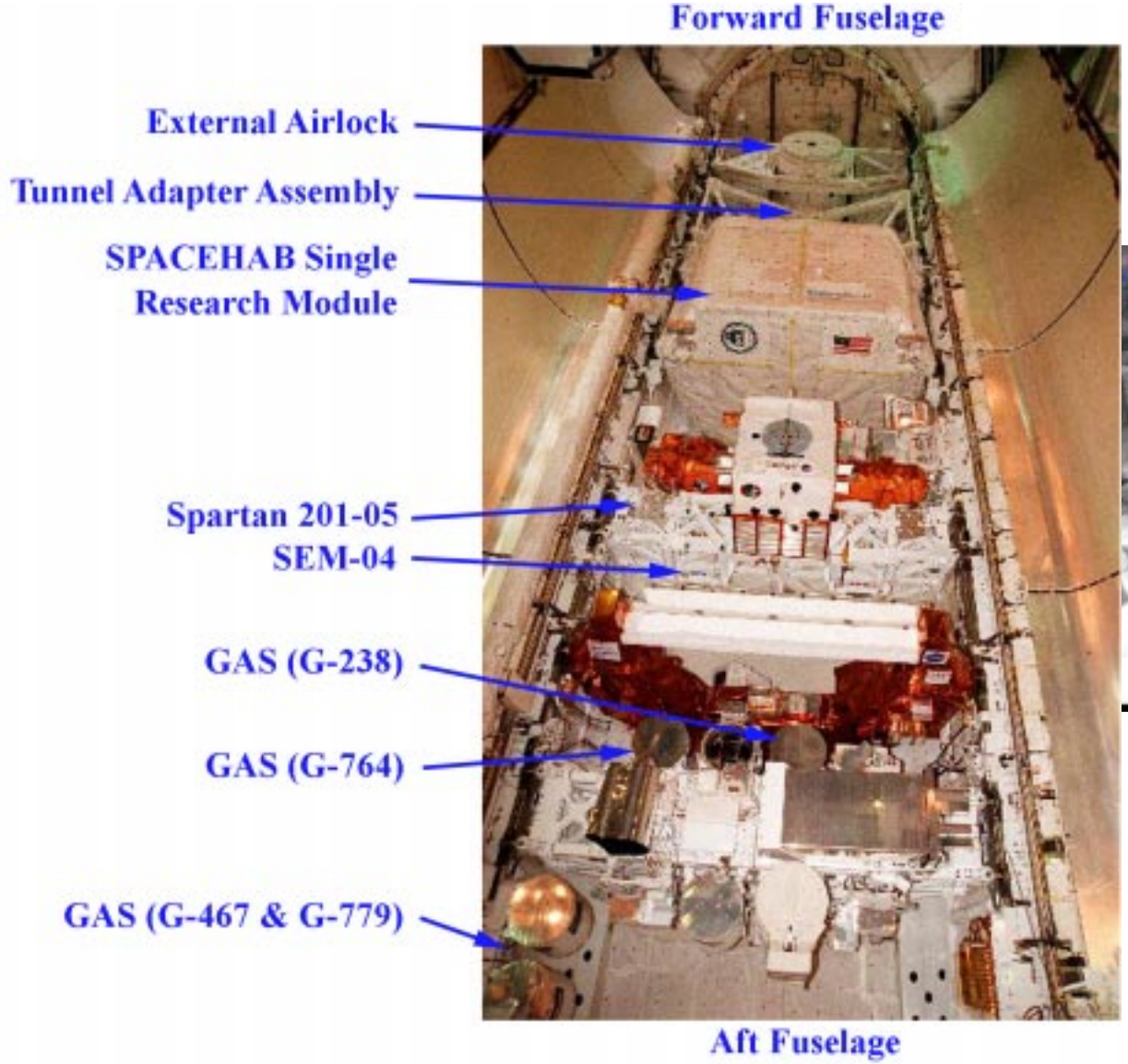
- Experiment mounted to SEM mounting plate
- SEM stacked in SEM carrier system, which provided power and timeline and data storage
- SEM carrier system placed in GAS canister



NASA Photo

† http://sspp.gsfc.nasa.gov/sem/experimenter/descriptions/module.html
‡ http://sspp.gsfc.nasa.gov/sem/experimenter/descriptions/support.html

Shuttle Integration and Flight



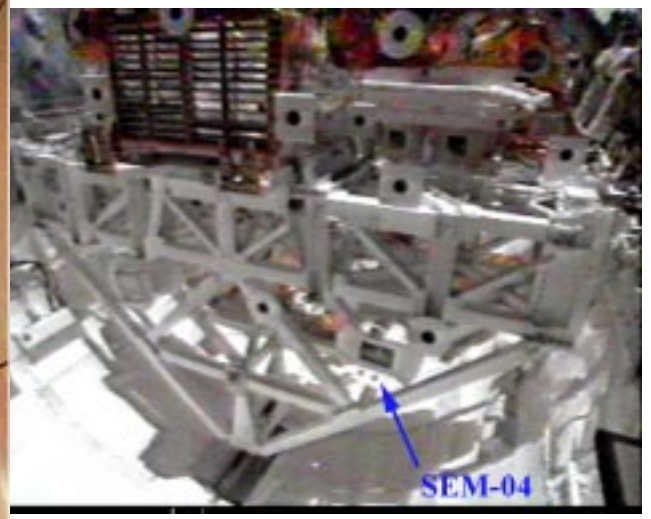
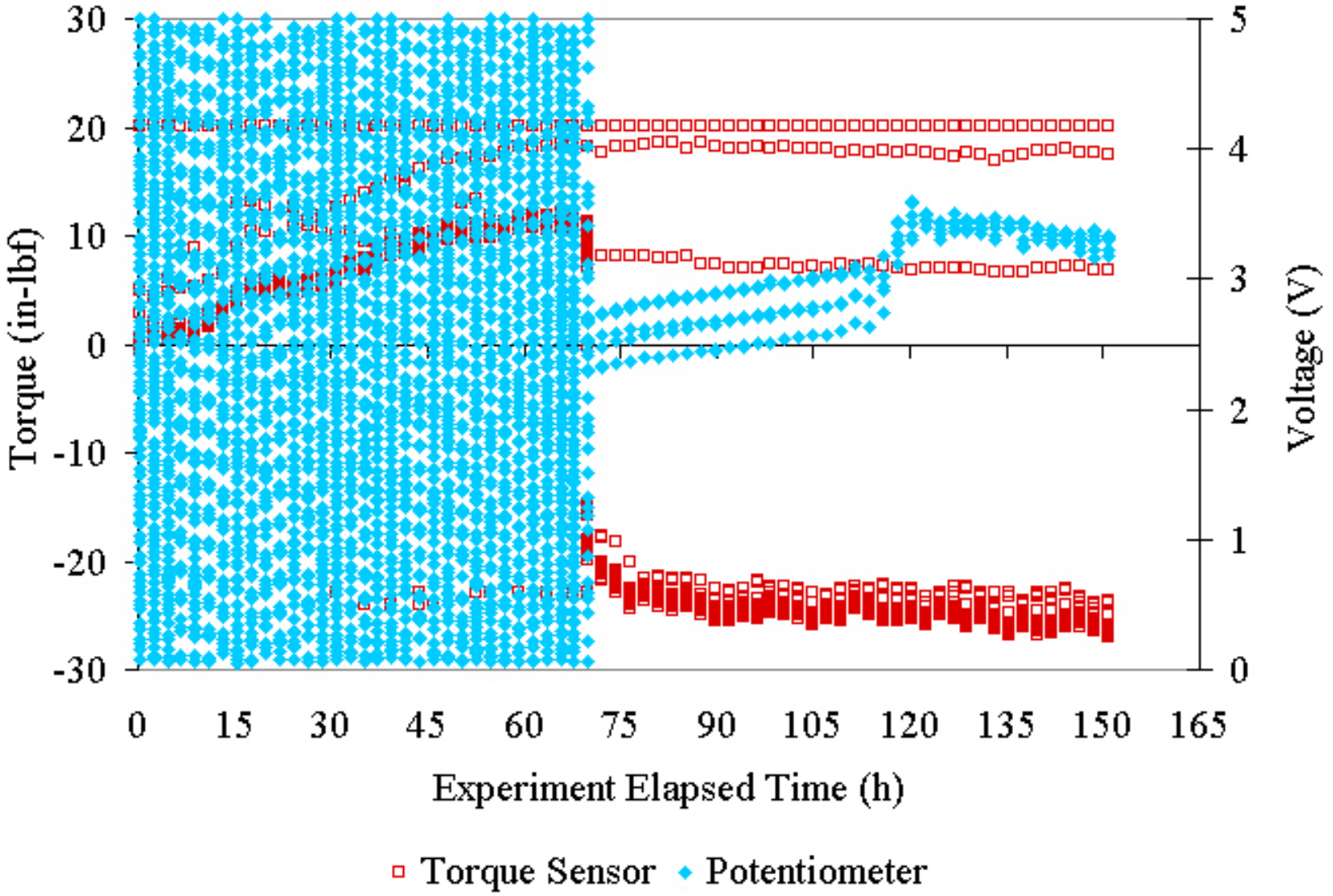


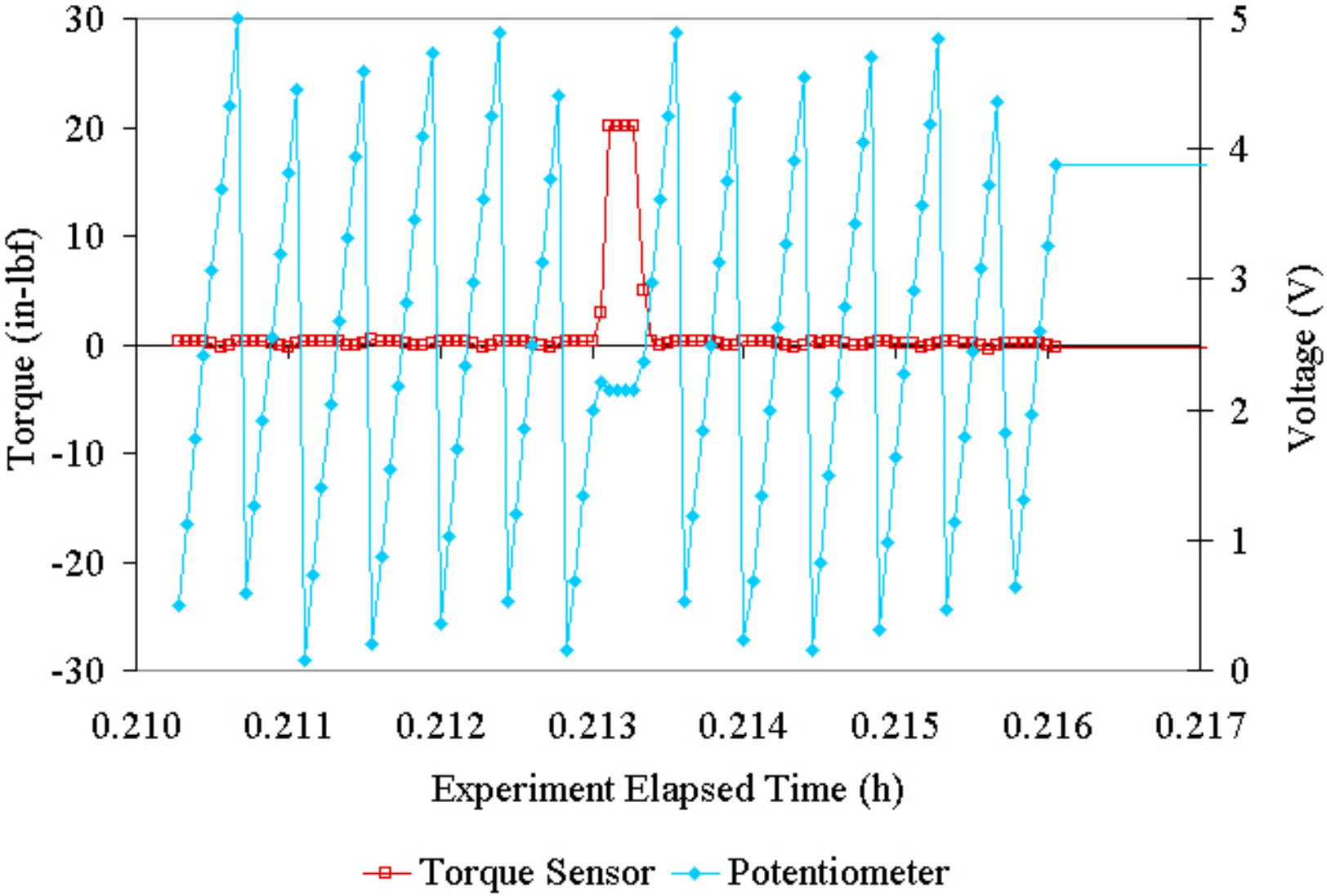
Photo captured from NASA TV

http://crystalball.gsfc.nasa.gov/sp201/sts95/pict91.html

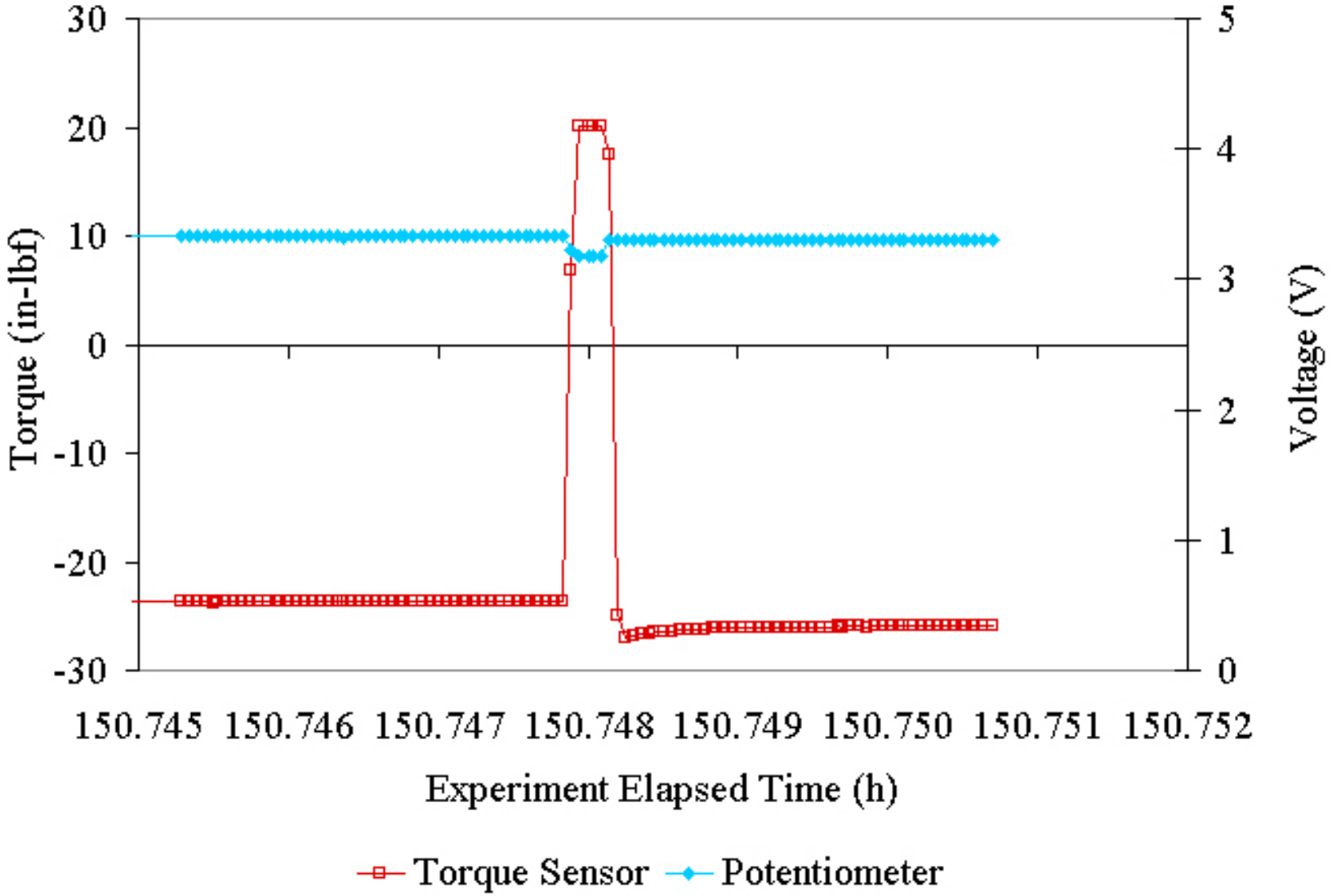
SEM Experiment Data



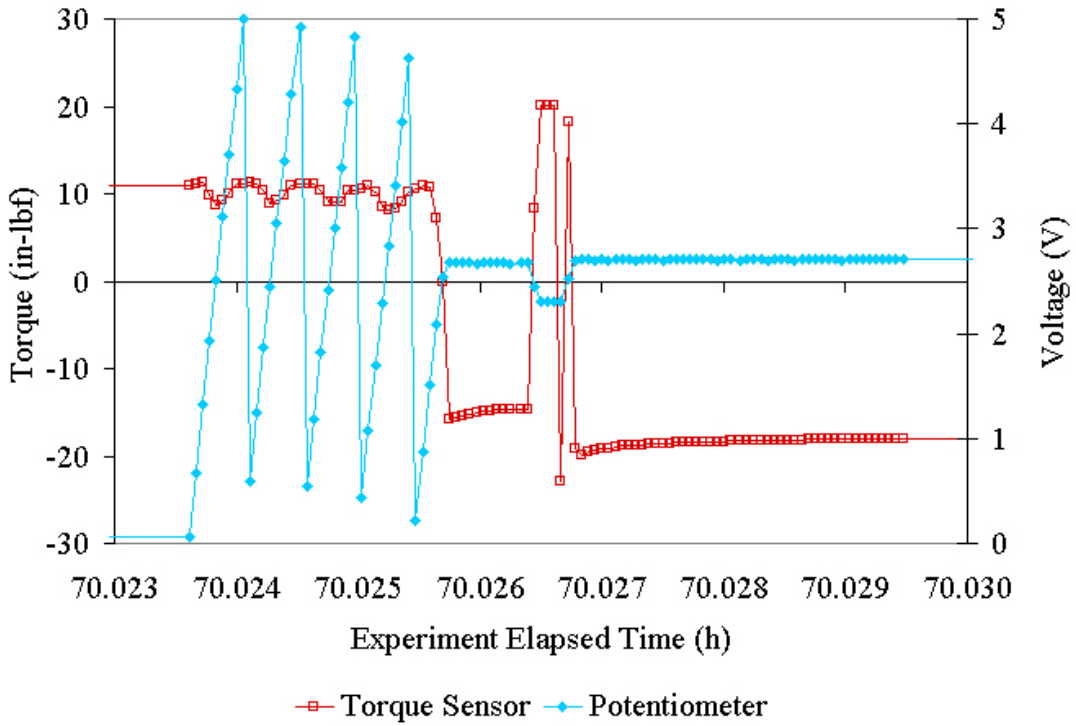
First Data Run

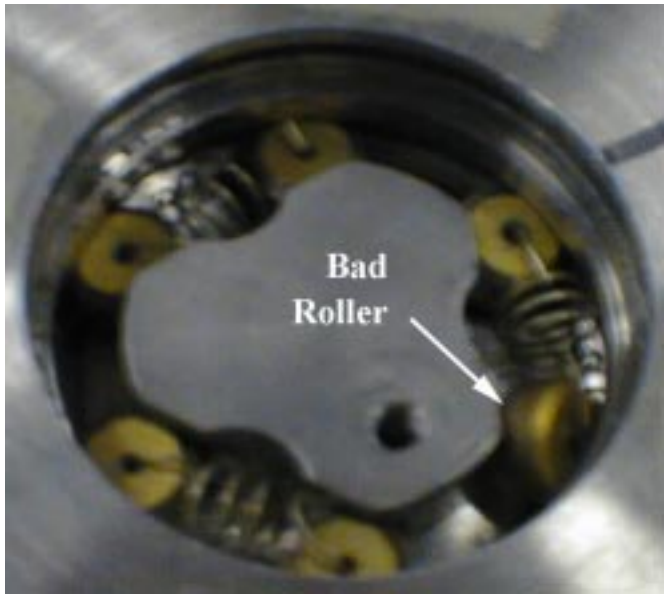


Last Data Run (Data Run 70)



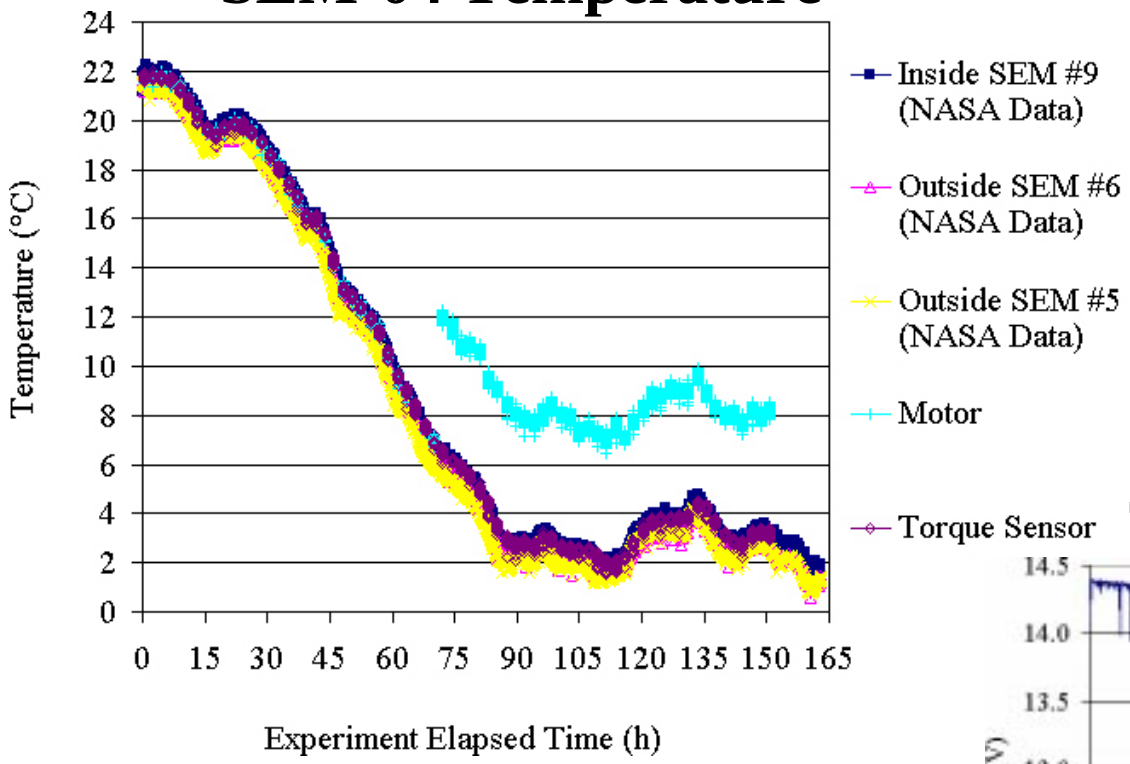
Data Run 33

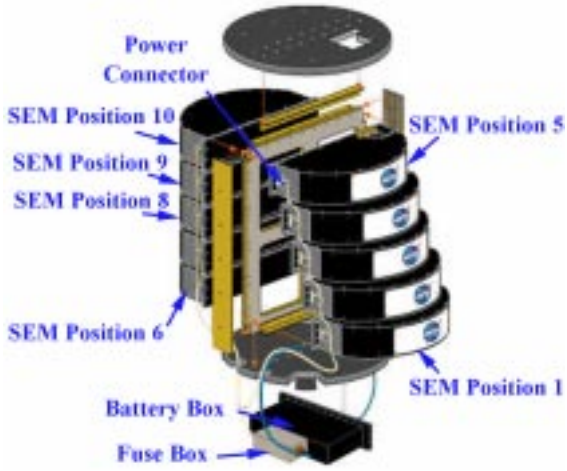

30
20
10
0
-10
-20
-30
Torque (in-lbf)
5
4
3
2
1
0
Voltage (V)
70.023
70.024
70.025
70.026
70.027
70.028
70.029
70.030
Experiment Elapsed Time (h)
Torque Sensor
Potentiometer


Bad
Roller

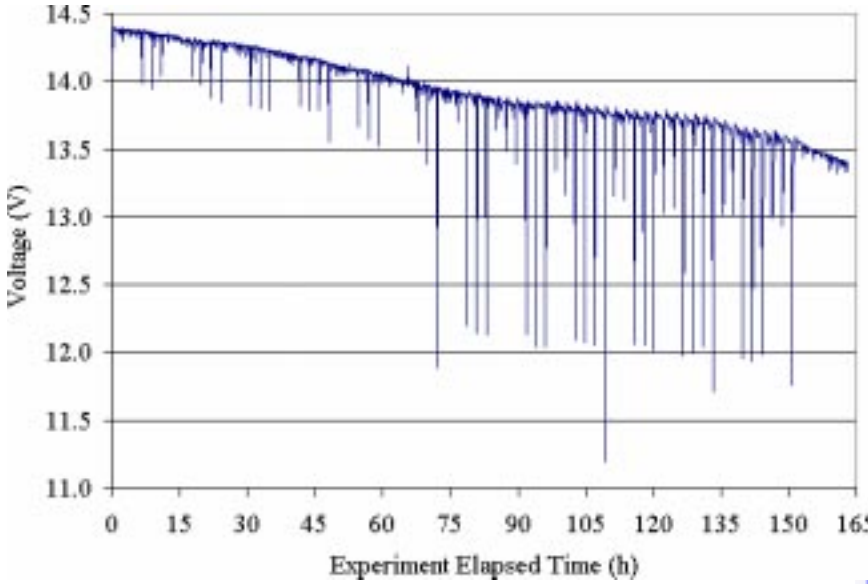
SEM-04 Temperature and Battery Voltage

SEM-04 Temperature





SEM-04 Battery Voltage



Lessons Learned and Future Plans

- Lessons learned
  - Zero-torque calibration when nothing was moving would have been useful
  - Intensive series of ground tests limited by earlier than expected experiment delivery date
  - Timeline and data collection driven by SEM software
- Plans for 3-D roller mechanism
  - Evaluate “deeper” groove/modified spring design
  - Failure test mechanism
  - Further quantify back drive torque (SEM data showed 2.0 ± 1.5 in-oz at beginning of life)